Review on Image Enhancement in Spatial Domain

Manish Kumar Saini, Deepak Narang
Department of Electrical Engineering
Deenbandhu Chhotu Ram University of Science and Technology, Murthal, Sonepat, Haryana, India
E-mail ID: - narang.deepak01@gmail.com

***Abstract*- With the proliferation in electronic imaging devices like in mobiles, computer vision, medical field and space field; image enhancement field has become the quite interesting and important area of research. These imaging devices are viewed under a diverse range of viewing conditions and a huge loss in contrast under bright outdoor viewing conditions; thus viewing condition parameters such as surround effects, correlated color temperature and ambient lighting have become of significant importance. Therefore, Principle objective of Image enhancement is to adjust the quality of an image for better human visual perception. Appropriate choice of enhancement techniques is greatly influenced by the imaging modality, task at hand and viewing conditions. Basically, image enhancement techniques have been classified into two broad categories: Spatial domain image enhancement and Frequency domain image enhancement. This survey report gives an overview of different methodologies have been used for enhancement under the spatial domain category. It is noted that in this field still more research is to be done.**

***Index Terms*- Image Enhancement, Spacial domain, Optimization.**

I. Introduction

The image enhancement is done for better understanding of data in images for human visual or to provide better input for other automated image processing techniques. Spatial domain methods and the frequency domain method are the two categories of image enhancement method. Direct operation on image pixels, comes under the category of spatial domain method whereas frequency domain methods, involve Fourier transform of an image for its operation. But unfortunately when it comes to human understanding, there is no generalize theory for determining: what actually good image enhancement is? Though when image enhancement method act as pre processing tool for other image processing methods then quantitative measures can decide which techniques are most suitable.

Basically an Image contrast is defined as the unlikeness or difference in color and lightness between parts of an image. Alas_ a general definition for image contrast does not exist which can be suitable for all situations. As the the visual appearance of an object depends on many factors such as luminance, edges and texture of the object of interest and the background, luminance and the immediate surround of the object, color, motion, and many other high level factors. It becomes very difficult to define a contrast measure considering all above factors. Some models defined the contrast measure which is limited to some factors and it also influence the understanding of contrast. Two major classes of contrast definitions are: first class does not take into account the frequency sensitivity of the human visual system, and the second class take into account, implicitly or explicitly, some of information processing characteristics of the visual cortex, such as frequency and orientation selectivity.

It's seen that the contrast enhancement is usually referred as most vital issue in image processing. Images acquired by line CCD cameras or other kinds of cameras may sometimes exhibit low contrast because of restrained imaging conditions. Generally these low contrast images need be enhanced in order to be suitable for desired applications. In the coming sections different contrast enhancement techniques have been discussed.

II. Comprehensive Review and Analysis of Literature

Histogram equalization (HE) as in [1] is the well known or usually used technique for contrast enhancement because of its simplicity and comparatively better performance on almost all types of images. HE based on remapping the gray levels of the image based on the probability distribution of the input gray levels. HE methods can be classified in two principle categories–global and local histogram equalization. Global Histogram Equalization (GHE) uses the histogram information of the entire input image for its transformation function. However, this global approach is suitable for overall enhancement; it fails to adapt with the local brightness features of the input image. Gray levels with very high frequencies, dominate the other gray levels having lower frequencies and in such a situation, remapping of gray level is done by GHE in a manner that the contrast stretching becomes limited in some dominating gray levels having larger image histogram components and causes powerful contrast loss for other small ones. Local histogram equalization (LHE) can be free from such problem. It uses a small window that slides through every pixel of the image sequentially and only the block of pixels that fall in this window are taken into account for HE and then gray level mapping for enhancement is done only for the center pixel of that window. Hence local information get properly used. LHE has some disadvantages: (i) it requires high computational cost; (ii) it sometimes causes over-enhancement in some portion of the image; (iii) it enhances the noises in the input image along with the image features. To get rid of the high computational cost, another approach is to apply non-overlapping block based HE. Although, mostly time, these methods produce an undesirable checkerboard effects on enhanced images [1, 2].

Some researchers have also focused on improvement of histogram equalization based contrast enhancement such as mean preserving bi-histogram equalization (BBHE) [3], equal area dualistic sub-image histogram equalization (DSIHE) [4] and minimum mean brightness error bi-histogram equalization (MMBEBHE) [5].

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In [6] authors proposed an extended form of bi-histogram equalization called bi-histogram equalization with neighborhood metric (BHENM). BHENM consisted of two stages. First, large histogram bins that caused washout artifacts were divided into sub-bins using neighborhood metrics; the same intensities of the original image were arranged by neighboring information. In the next stage, based on the mean of the histogram of the original image the original image had been divided into two sub-histograms; now they were equalized independently using refined histogram equalization, which produced flatter histograms. In an experimental trial, BHENM simultaneously cared for the brightness and enhanced the local contrast of the original image. on the other hand the limitation is that the execution time of this method was three times higher than that of GHE.

In this area, M. A.-A.-Wadud et al. [7] proposed a dynamic histogram equalization method which partitioned the image histogram based on local minima and gray level ranges has been assigned specifically for each partition before equalizing them separately. These partitions further go through a repartitioning test to confirm the absence of any dominating portions. Chen and Nor Ashidi in [8] further modified this effort, where quadrants dynamic histogram equalization (QDHE) algorithm separated the histogram into four (quadrant) sub-histograms based on the median of the input image. Now before new dynamic range was assigned to each sub-histogram, the resultant sub-histograms were curtailed according to the mean of intensity occurrence of input image. Finally, each sub-histogram was equalized.

In [9] authors have given priority to the contrast enhancement of gray-level digital images while maintaining the mean image intensity preserved. This results in better viewing texture and effectiveness. The contrast enhancement was achieved by maximizing the information content carried in the image via a continuous intensity transform function. The preservation of image intensity was obtained by applying gamma-correction on the images. Since there is always a trade-off between the requirements for the enhancement of contrast and preservation of intensity, an improved multi-objective particle swarm optimization procedure was introduced to resolve this contradiction, making use of its flexible algorithmic structure. The effectiveness of the proposed approach was illustrated by a number of images including the benchmarks and an image sequence captured from a mobile robot in an indoor environment.

In [10] authors attempted to deal directly with colors of the image. In that LUV color space to enhance the image where each component was used to calculate the gradient value to which conventional enhancement techniques were applied. This work was extended in [11] where another characteristic of image i.e. color saturation was targeted to produce natural appealing in images. But this technique was not able to keep the image information intact.

Authors in [12] proposed a concept for changing the display of an image, by iteratively comparing the intensity with a pair of preset thresholds and, which indicated the satisfactory brightness and darkness, respectively, while processing the image until the threshold conditions were satisfied.

In [13] authors suggested a method in which by iteratively processing and comparing the average saturation with the preset threshold for appropriating the color saturation in natural scene images. Unlike grey scale images, there are some factors in color images like hue which need to be properly taken care of for enhancement. Hue, saturation and intensity are the attributes of color. Shade is that attribute of a color which decides what kind of color it is, i.e., a red or an orange. Original color gets changed if the shade gets changed and hence, distorting the image. One needs to improve the visual quality of an image without distorting it for image enhancement. In [14] authors offered a novel and effective way of tackling the range/scale problem during the pre-processing itself. In this way they used the HSV space for enhancement while shade was kept preserved. The proposed technique for noisy color images indeed enhanced the image but the clarity of the enhanced image was still poor.

In [15] authors proposed a similar approach by working only on the luminance component of HSV color space where the V component is divided into smaller blocks and then uses multiple steps to preserve the details. In [16] authors targeted the six kind of images -dark, low-contrast, bright, mostly dark, high-contrast, and mostly bright and proposed a decision tree based algorithm to enhance the contrast of those images simultaneously. The statistical features of luminance component were extracted to which decision tree based classifier was applied to find that six categories. This approach did not require any human intervention i.e. was automatic and parameter free. Image enhancement is one of the intriguing and influential issues in digital image processing field. Image enhancement can be treated as transforming one image to another so that the look and feel of an image can be improved for machine analysis or visual perception of human beings. The main purpose of image enhancement is to bring out details that are hidden in an image, or to increase the contrast in a low contrast image.

In [17] authors presented another technique of enhancement for low illumination conditions and to minimize the loss of edge sharpness by combining space variant luminance map (SLVM) and conventional gamma correction which developed the two dimensional gamma correction. The down/up scaled Gaussian masking derived the benefit of the complexity reduction for the local brightness characterization. Though image enhancement methods improve the visual perception of the image but there exists some deficiencies in most enhancement techniques. Authors in [18] worked on those deficiencies which they found in form like loss of details, gray-world violation and loss of local contrast and proposed the image fusion method, based on local contrast detail, to minimize these losses. One more effective step towards image enhancement field had been presented in [19] where authors made the use of genetic algorithms to overcome the produced artifacts in images. The proposed method used a simple and novel chromosome representation together with corresponding operators. The results of this method were found better especially for the low-illuminated images with high dynamic range. In [20] authors presented another use of GA in the field of image enhancement. In this work, a weighted combination of four types of nonlinear transforms (s-curves) as a transformation function was used.

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GA was used to find the optimized values of weighting coefficients by making use of objective measure of image Brenner's measure and some noise information. However, this approach was not able to deal with the ambiguities present in an image. In [21, 22] authors explored the applicability of fuzzy set theory to image enhancement field. These fuzzy rules allow a processing work to be defined in terms of human-like reasoning. In [21] the presented work was based on minimization of compactness and of fuzziness. Whereby, it was possible to obtain both fuzzy and non-fuzzy (threshold) versions of an ill-defined image. The incorporation of fuzziness in the spatial domain made it possible to provide more meaningful results than by considering fuzziness in grey level alone. Different bandwidth membership function using a blurred chromosome images were taken to show the effectiveness of the algorithm. In [22] authors presented a fuzzy operator which was able to maintain a balanced strength between sharpening and noise-suppressing components according to the properties of the input data and allowed a user to design a general fuzzy rule base without taking care of the particular scene to be processed.

The work presented in [21] was based on classical fuzzy enhancement method which was not fit for the images of low contrast. To deal with this problem, authors bestowed a generalized iterative fuzzy enhancement algorithm in [23]. The image quality assessment was based on the statistical features of the gray-level histogram and the computer simulation results showed that this new enhancement method was more suitable than classical fuzzy enhancement. In [24] author approached a new visionary work by introducing an optimization technique with fuzzy approach. Authors transformed the image into fuzzy domain on the basis of maximum fuzzy entropy principle and the parameters which could shape the membership function in proper domain were optimized by genetic algorithm optimization technique. The method selected the fuzzy region according to the nature of the input image and image could keep as much information as possible after being transformed. Many authors have put their work in image enhancement field with fuzzy approach in their own way. Like authors in [25] proposed a Gaussian type of fuzzification function which was composed of two parameters - a single fuzzifier and a new intensification operator called NINT. Fuzzifier was obtained by maximizing the fuzzy contrast and the NINT parameter was obtained by minimizing the entropy. This work was limited to the enhancement of gray images only. In [26] authors extended the approach in [25] for the enhancement of color images. In that work histogram was considered as the basis for fuzzy modeling of color images. The two parameters ('index of fuzziness' and 'entropy') were defined to represent the quality of an image in fuzzy domain.

Authors in [27] again refined the work of [25, 26] introduced a global contrast intensification operator (GINT), which was based on three parameters, viz., intensification parameter, fuzzifier, and the crossover point. Gaussian membership function had been used to fuzzify the image information in spatial domain. To get the image information fuzzy contrast factor and visual factor were defined. To render the image quality fuzzy entropy based objective function was laid out but this work showed improvement for underexposed images. The extension of this work was given in [28, 29] extended the work of [27] for the overexposed images also. In those work images were fuzzified on the basis of an parameter called as 'Exposure'. In [28] the image was partitioned in two regions- underexposed and overexposed region and introduced a new bio-mimicry based optimization algorithm, i.e. Bacterial Foraging Optimization to minimize the fuzzy entropy based objective function. And in [29] the partition was into three regions- under, over and mixed region. The evolutionary algorithm was based on the social behavior of an ant known as Ant Colony Optimization.

III. Conclusion

Image enhancement algorithms offer a wide variety of approaches for modifying images to achieve visually acceptable images. The choice of such techniques is a function of the specific task, image content, observer characteristics, and viewing conditions. The point processing methods are most primitive, yet essential image processing operations and are used primarily for contrast enhancement. The histogram of an image (i.e., a plot of the gray level frequencies) provides important information regarding the contrast of an image. Histogram equalization is a transformation that stretches the contrast by redistributing the gray-level values uniformly. This paper presented the different forms of histogram equalization for gray scale contrast enhancement. Fuzzy approach has been a significant tool in the area of color image enhancement which is able to make the information content effective. Although we did not discuss the computational cost of enhancement algorithms in this article it may play a critical role in choosing an algorithm for real-time applications. Despite the effectiveness of each of these algorithms when applied separately, in practice one has to devise a combination of such methods to achieve more effective image enhancement. But research never ends and still this work is like tip of the iceberg and needs more and more advancement for image enhancement techniques.

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